



‘Awa Dieback in Hawaii

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Awa dieback is a severe viral disease of ‘awa (*Piper methysticum*). ‘Awa (ah'-vuh) is the Hawaiian word for “kava,” the name by which this plant and its products are more generally known outside Hawaii. This disease is the most important cause of kava yield reduction in the South Pacific (Davis 1999, Lebot 1997), where it is called kava dieback, and it also causes significant yield loss and plant death in Hawaii. Since the first confirmed observation of ‘awa dieback on the island of Hawaii in 1999, all common Hawaiian varieties have been found susceptible. The disease is particularly damaging to young plants and has destroyed many acres of ‘awa in some locations.

Hawaiian ‘awa varieties show a wide range of disease symptoms. All Hawaiian ‘awa varieties with dieback that have been tested were positive for cucumber mosaic virus (CMV, formerly known as cucumber mosaic virus), the primary cause of the disease (Davis et al. 1996). Plants with ‘awa dieback symptoms and CMV have been confirmed on the islands of Hawaii, Molokai, Maui, and Kauai. This disease can spread rapidly from area to area through the propagation and transport of infected planting material, and within planting locations it is spread from plant to plant by viruliferous aphids, ones that have fed on virus-infected plants and retain the virus. Without proper disease management practices, dieback poses a significant threat to Hawaii’s ‘awa industry.

Disease symptoms

A wide range of symptoms characterize ‘awa dieback in Hawaii. Whole-plant symptoms include stunting, wilting, yellowing, and poor growth. Stems may have brownish-black lesions on their nodes and internodes, brown or black internal soft rot, blackened veins, and they may wilt, split, or collapse and ultimately die. Leaves may have puckered (rugose), curled blades and may droop and ultimately die. Leaves may also have black, yellow, or “cleared” veins; yellow mosaic patterns between the veins; drooping and necrotic petioles; brown ringspots;

brown leaf spots; or diffuse yellow blotches. Severely affected plants have rotten basal stems and stumps and black, rotten roots.

Symptoms of ‘awa dieback may resemble other ‘awa diseases or conditions. The mosaic symptoms associated with ‘awa dieback resemble nutrient deficiencies (e.g., nitrogen, potassium, and iron) caused by insufficient fertilizer applications or planting in a nutrient-poor soil or medium. Stunting, yellowing, and wilting from ‘awa dieback resemble foliar disease symptoms associated with root-knot nematodes (*Meloidogyne incognita*) and pythium root rot caused by the fungus *Pythium splendens*. Wilting and collapse of plants from ‘awa dieback may resemble fertilizer burn, which leads to rotting of roots, or drought stress. ‘Awa dieback may be difficult to distinguish from leaf chlorosis or abnormality resulting from genetic anomalies or mutations. The rugosity and leaf curling associated with systemic infection of ‘awa by CMV may also be caused by feeding of nonviruliferous aphids. Blackening of entire leaf veins, which in ‘awa dieback is more often visible on both upper and lower leaf surfaces simultaneously, can be confused with damage caused by feeding of thrips (banana silvering thrips, *Hercinothrips bicinctus*), which causes a prominent blackening, often adjacent to veins, on the underside of ‘awa leaves. Veinal necrosis of plants with ‘awa dieback is mimicked by blackening of broken veins resulting from mechanical or wind damage. Leaf necrosis of ‘awa dieback can resemble the leaf curling and discoloration caused by mite feeding (e.g., carmine spider mite, *Tetranychus cinnabarinus*). Leaf curling and discoloration of plants with ‘awa dieback may resemble the mild sunburn damage (leaf curling, mild mosaic pattern, and yellowing) developed on young plants when they are moved from partial shade in nurseries into full sun. Ringspots associated with ‘awa dieback resemble the small, ringspot-like lesions on young ‘awa leaves caused by a fungal pathogen, *Colletotrichum* sp., which are similar but generally smaller.

Cause of 'awa dieback

The primary cause of 'awa dieback is the systemic infection of 'awa by cucumber mosaic cucumovirus (Davis et al. 1996). Virus transmission experiments with mechanical sap inoculations and transmission by the melon aphid (*Aphis gossypii*) have confirmed that CMV is responsible for foliar symptoms associated with the disease (mosaic, dieback, black veins) (Davis et al. 1996, and the author's unpublished studies). In Hawaii, CMV has been detected from the roots, stems, and leaves of 'awa plants showing dieback symptoms. Most plants with symptoms of 'awa dieback in Hawaii have tested positive for CMV.

CMV has worldwide distribution. The virus is known for its broad host range and propensity to form new strains. CMV is known to infect over 800 different plant species, including many common weeds and vegetable crops found in Hawaii. Not all CMV strains can infect all of the known CMV-susceptible plant species. Apparently, many ancient stands of 'awa in remote forest locations still remain free of dieback symptoms.

The symptoms of 'awa dieback vary among 'awa varieties, locations, and environments. This variation in symptom expression makes visual assessment and 'awa dieback diagnosis difficult. As described above, 'awa plants under various stresses may have symptoms similar to 'awa dieback, and the same stresses may also result in enhanced severity of leaf and stem symptoms resulting from CMV infection. For example, undernourished, drought-stressed, or nematode-infected plants can wilt and die back more quickly than unstressed plants infected with CMV. The most severe foliar symptoms tend to occur in unshaded or drought-stressed 'awa plantings. Dieback symptoms on 'awa plants are generally more severe and widespread in areas where there are weed hosts of CMV or where high populations of the melon aphid and ants are prevalent. 'Awa dieback can become established and spread rapidly in large populations of 'awa plants cultivated without windbreaks or tree cover, plantings which are thus relatively open, and in plantings exposed to neighboring farms and unprotected by windbreaks or other barriers.

'Awa dieback disease cycle

Virus transmission and dispersal

In Hawaii, 'awa dieback and CMV are spread primarily by two methods: (1) feeding by insect vectors (aphids),

and (2) mechanically, by selecting node cuttings ("knuckles") or tip cuttings from diseased plants for propagation, or by cutting stems with tools contaminated with infected plant sap (transfer on tools is presumably possible, but it has not been proven to occur). Experiments with virus transmission have shown that CMV can be spread by melon aphid feeding and by mechanically wounding and rubbing 'awa leaves with infected plant sap or purified virus. The melon aphid acquires and transmits CMV by probing infected plant cells with its stylets.

Inoculation and infection

After an infested (viruliferous) melon aphid introduces CMV into the living cell of a healthy leaf, the processes of infection and disease begin. CMV and other plant viruses must have a living host to survive, because viruses have no metabolism of their own. They cause disease by taking over certain plant cellular activities and making millions of copies of themselves within plant cells. After a period of time, virus particles move between adjacent cells in the leaf until the virus spreads into the vascular system. Once in the phloem, CMV virus particles can move rapidly through the veins to the roots and throughout the rest of the plant system.

Symptom development

As cells and tissues become filled with plant virus particles, they show symptoms of necrosis and can eventually die. This explains the browning of tissues associated with dieback, especially the leaf and stem veins and roots. The yellow mosaic patterns or blotches within leaves are caused by damage to chloroplasts and the loss of chlorophyll from leaf cells.

Disease spread and plant dieback

Eventually, as roots and stems become rotten, they die back either partially or completely, especially if the uptake and transport of water is interrupted. If systemic infection occurs in very young plants, they may wilt rapidly. Older plants may survive the disease if the infected stems die back before CMV spreads systemically throughout the plant's tissues to the stump and other stems.

As aphid populations increase, 'awa dieback can spread rapidly through a field, especially if there are weed hosts that are not controlled and if aphid-tending

ant populations are high. Winged (alate) aphids can carry CMV for some distance when blown by wind. Several ant species are known to tend the crawling stages of melon aphid, protecting and carrying them from plant to plant within fields. These ants include the longlegged ant (*Anoplolepis longipes*), bigheaded ant (*Pheidole megacephala*), Argentine ant (*Iridomyrmex humilis*), and a *Paratrechina* species.

In early stages of epidemic development, plants with foliar or dieback symptoms tend to be located at the edge of fields and in clumps or patches. Spread of disease symptoms throughout a field may be more rapid for younger plants and less rapid for more mature plants. Older plants, or mature plants with more stems, are more tolerant of the disease and tend not to die back completely after they are initially infected.

Survival of CMV

Cucumber mosaic cucumovirus requires a living plant host to survive extended periods of time and to replicate. Thus by destroying infected plant tissues and organs, one can destroy the virus. CMV can survive short periods of time within the mouthparts of the melon aphid and within fresh stem cuttings used for propagation. Presumably, CMV can survive for short periods in plant sap on tools used for cuttings. CMV is not known to survive in water or soil.

Control and management of 'awa dieback

All known Hawaiian 'awa varieties are susceptible to CMV and dieback. However, the Papua New Guinea variety 'Isa' may be resistant to Hawaii's 'awa strain of CMV, if the author's observations are confirmed by inoculation tests. 'Isa' has not tested positive for CMV in Hawaii, nor has it shown any symptoms of 'awa dieback, despite being a good host of the melon aphid and its exposure to CMV within fields of 'awa varieties with both severe 'awa dieback symptoms and high populations of the melon aphid. Evaluation of 'awa varieties from other areas in the Pacific and other Hawaiian varieties from existing, native stands should be done to find resistant varieties that may be suitable for planting in Hawaii. Lacking a suitable selection of resistant varieties appropriate for economic 'awa production, 'awa growers in Hawaii must pay special attention to strategies to manage this disease in plantings of Hawaiian 'awa varieties, as outlined in the following paragraphs.

Best management practices for 'awa dieback prevention

- Establish and maintain good overall plant health and vigor by periodic and appropriate fertilizer applications, irrigation when needed, and control of nematodes and root rot. (For more on nematodes, see CTAHR publication PD-15, *Plant-parasitic nematodes and their management*.)
- Learn to recognize the symptoms of 'awa dieback illustrated in this publication and to distinguish them from other diseases with related symptoms.
- Use care in selecting healthy stems for propagation. Avoid plants with dieback symptoms and strive to start nurseries with virus-free cuttings. Inspect all plants obtained from nurseries or other sources for symptoms of the disease. "Mother plants" should be tested for the presence of CMV ("indexed for CMV") by a diagnostic laboratory before nodes are used for propagation. Interpret indexing results with caution, because CMV may not be fully systemic within an infected plant (Davis et al. 1996). When possible, isolate newly obtained plant materials from existing plantings until their condition can be assessed.
- Eradicate all weed hosts of CMV, such as honohono grass (*Commelina diffusa*) and the pasture legume glycine (*Neontonia wightii*, syn. *Glycine wightii* and *G. javanica*). Symptoms of CMV infection of honohono grass and glycine include leaf yellowing, mosaic, and diffuse ringspots.
- Eliminate hosts of the melon aphid, including honohono grass and common vegetables, near 'awa plantings.
- Control ants and aphids, especially in 'awa nurseries and young plantings; aphids can be controlled by applications of soap or oil-based sprays.
- Rogue (remove) infected plants and plant parts. This control measure has been found effective in the South Pacific (Davis and Brown 1996). Rogueing minimizes the overall damage and yield reduction and slows the rate of disease spread within and among plants. The objective of rogueing is to remove diseased tissue and prevent systemic infections. Rogueing recommendations are as follows:
 - Destroy all infected plants that are approximately nine months of age or less as soon as they show symptoms; young plants or plants with few stems are likely to have or develop systemic infections rapidly.

'Awa dieback—leaf and petiole symptoms



Yellow leaf mosaic



Intense mosaic



Necrotic ring mosaic



Blackened leaf veins



Rugose pucker of leaf



Uniformly puckered leaf, blackened and drooping petiole, and yellow leaf mosaic



Leaf curling, rugosity, mosaic, and failure to unfurl

Leaf and petiole symptoms

Plants in the early stages of 'awa dieback express one or more leaf or petiole symptoms. Some of the common leaf symptoms (mosaic, curling, and rugosity) appear most often on the youngest, unfurling leaves, whereas other leaf symptoms (drooping petioles, blackened and puckered veins, ringspots) may show on 'awa leaves of all ages or at any position on the plant. Leaf symptoms are an early warning and usually precede the more severe symptoms shown on stems, whole plants, and roots. Young plants with any of these leaf symptoms should be tested for CMV and pruned or removed entirely.



Ringspots

‘Awa dieback—stem and whole-plant symptoms



**Advanced dieback,
with rotten stems
and chlorotic leaves**



**Stem lesion and collapse (above)
and internal stem necrosis (below)**

Stem and whole-plant symptoms

Plants in more advanced stages of dieback express one or more of these whole-plant and stem symptoms. As CMV infects and moves systemically through the veins, plants begin to grow slowly, droop, turn yellow, or wilt suddenly. As CMV accumulates in stem tissues, internal soft rot and external stem lesions develop. Eventually, individual stems die back or collapse. Invasive fungi and bacteria can enter dead stems, leading to severe basal stem and root rots. CMV has a wide host range, including the common weed, honohono grass (here showing the typical yellow ring mosaic).



Stunting, wilting, yellowing, drooping, and veinal necrosis



Basal stem and stump rot



**Honohono grass
infected with CMV**



**A healthy ‘awa planting,
free of dieback symptoms**



Two young ‘awa plants: wilted vs. healthy

- If leaf or stem symptoms of 'awa dieback appear on plants older than nine months (or plants with many stems), prune or break off the symptomatic stems, leaving at least two nodes above soil level (if stems are severed too close to the soil, there is increased likelihood of fungal and bacterial rots developing in the wounded stems and eventually the stumps).
- Remove and destroy entire stems, not just the infected leaves, because CMV can persist as a latent infection—that is, the virus may spread within stems and throughout the plant before disease symptoms appear.
- If entire plants are wilting, regardless of age, they should be removed and destroyed.
- If large aphid populations are observed on plants with dieback, consider applying a pesticide such as an insecticidal soap before the rogueing operation to prevent viruliferous aphids from spreading to nearby plants.
- Avoid using pruning shears on healthy plants just after cutting diseased plants unless the blades are first disinfested with a flame or a general-purpose sterilant acceptable for agriculture use.
- Intercrop 'awa with plants that are known not to be susceptible to CMV, and avoid intercropping with common vegetable crops, such as cucumber. Possible intercrops for 'awa that are not hosts of CMV include the indigenous Hawaiian crops *kalo* (taro, *Colocasia esculenta* L.), *'uala* (sweetpotato, *Ipomoea batatas* L.), and *niu* (coconut, *Cocos nucifera* L.), as well as most other plant species endemic to Hawaii. Contact the CTAHR Cooperative Extension Service about the risk of growing specific plants within or near 'awa plantings.
- Use windbreaks around and within 'awa fields to block aphids from entering and moving around the field. False wiliwili (*huala-ula-ula*, *Adenanthera pavonina* L.) is a fast growing, effective windbreak for field perimeters.
- Consider growing 'awa under shade. Shade appears to reduce the severity of 'awa dieback symptoms. Use of shade, however, may create high humidity in the 'awa canopy that may enhance the incidence and severity of other 'awa diseases, such as leaf spots caused by fungi (unpublished observations of the author). Also, shade trees may have aggressive root systems and foliage that compete with the neighboring 'awa plants for moisture, nutrients, and sunlight.

- Observe strict quarantine precautions when shipping or transporting 'awa plants onto farms or into regions that have not reported dieback.

For updates to this information on 'awa dieback, visit the CTAHR Web site, <<http://www2.ctahr.hawaii.edu>>, and consult the Farmer's Bookshelf database.

Summary of plant and pest interactions

Potential CMV hosts

More than 800 plant species in 19 plant families are known to host cucumber mosaic cucumovirus. Plants that pose potentially high risk as CMV reservoirs when planted near 'awa in Hawaii and the Pacific include:

banana, beans, capsicum, carrot, clover, cucumber, eggplant, glycine, honohono, passionfruit, pea, peanut, pumpkin, spinach, squash tomato, tobacco, wild mustard.

Hosts of *Aphis gossypii*

Some plants are hosts of the melon aphid, one of the most common and destructive aphids in Hawaii and the most prevalent aphid on 'awa in Hawaii. (Other aphid species are known to transmit CMV in other parts of the world.) The following plants pose a high risk as aphid reservoirs when planted near 'awa:

aparas, avocado, banana, bidens, cucumber, edible gourds, eggplant, flowering ginger, glycine, honohono, hibiscus, lamb's quarters, malva, noni, shepherd's purse, taro, ti, tomato, zucchini, others.

CMV-resistant plants for intercropping

Only plants that are relatively low risk in relation to 'awa dieback should be considered as intercrops for 'awa. The following plants are not susceptible to CMV and are not known to be significant hosts of the melon aphid:

yam, cassava, edible ginger, sugarcane, coconut, vanilla, coffee, ferns.

Windbreaks

Windbreaks are useful for impeding aphid movement and for providing shade and wind protection for 'awa. Suitable species for use in Hawaii include the false wiliwili, 'Tropic Coral' erythrina, and most trees indigenous to the Pacific islands.

Ant pests

Ants pose high risk in 'awa plantings because they tend, protect, and disperse colonies of the melon aphid on 'awa and other host plants; species of particular concern are the bigheaded ant, Argentine ant, and longlegged ant.

Ant control in nurseries, shadehouses, and greenhouses is an essential component of virus-free 'awa plant production. The ants carry aphids into a nursery and place them within the unfurling leaves of young 'awa plants, where they tend the aphids and feed on their honeydew. The use of ant baits around the perimeter of the nursery and the use of barriers within the nursery (e.g., pans of water or sticky tapes at the base of legs of plant benches) should reduce the chance of ants entering the nursery and ascending the benches carrying aphids that will multiply within the facility.

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Pests of 'awa in Hawaii

Aphids

Melon aphid

Mites

Carmine spider mite

Broad mite

False spider mite

Ants

Longlegged ant

Bigheaded ant

Argentine ant

Scale

Coconut scale

Green scale

Barnacle scale

Hemispherical scale

Whitefly

Spiraling whitefly

Fringe guava whitefly

Caterpillars

Mexican leaf roller

Green garden looper

Thrips

Banana silvering thrips

Beetles

Chinese rose beetle

Grasshoppers

Narrowwinged katydid

Slugs

Gray garden slug

Black slug

Brown slug

Mealybugs

Root mealybug

Foliar mealybug

Planthoppers

Pigs

Rats

Diseases of 'awa in Hawaii

Disease	Associated* or causal organism	Disease	Associated* or causal organism
Fungal root rot	<i>Pythium splendens</i>	Root rot	excess salinity (fertilizer burn)
Fungal leaf spot	<i>Phyllosticta</i> sp. <i>Colletotrichum</i> sp.	Algal leaf spot	<i>Cephaleuros virescens</i>
Fungal stump and stem rot	<i>Fusarium</i> sp. <i>Rhizoctonia solani</i> <i>Nigrospora</i> sp. <i>Pythium splendens</i>	Root-knot nematode	<i>Meloidogyne incognita</i>
Fungal leaf blight	<i>Mycosphaerella</i> sp. <i>Colletotrichum</i> sp.	Lesion nematode	<i>Pratylenchus</i> sp.
Node rot	<i>Colletotrichum</i> sp. <i>Fusarium</i> sp. <i>Erwinia</i> sp. <i>Pseudomonas</i> sp.	Burrowing nematode	<i>Radopholus</i> sp.

*Proof of pathogenicity has not been established for some of these diseases.